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BACKWATER, CAUSED BY BRIDGE PIERS AND OTHER OBSTRUCTIONS, PLACED IN THE BEDS OF STREAMS.

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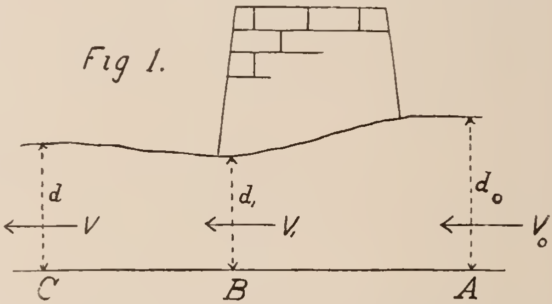
This problem is one which is probably incapable of exact solution, owing to the many uncertain and varying influences which are brought to bear upon it, whose character and mode of action we can not definitely determine. Nevertheless, we can obtain approximate results, which for all practical purposes will be sufficiently reliable and exact. For instance, let us suppose a river running with a constant flow, and that for some reason, we reduce its section one-half, by means of jetties built out from the shore, or bridge piers placed at intervals across the stream. This reduction of the cross-section would evidently cause the water above the obstruction to back up and increase in depth. The height to which the water rises may or may not be equal to the head necessary to produce the increase in velocity at the contracted section. For, as soon as the velocity is increased, the water begins to scour away the bottom in the contracted part, (if such bottom be not composed of rock,) and thus the area of that section is increased, its velocity diminished, and consequently the height to which the water rises is also decreased. Nevertheless, the *depth* of the water is increased, whether it be by scouring away the bottom, or the backing up of the water. It will generally be the case that the surface of the water will be elevated for some time

after the obstruction is built, but the bottom will gradually be scoured out by the increased velocity, until finally, owing to the increased depth, the contracted section will attain its original area, and the backed up water will subside.

Whenever the section of a stream is suddenly contracted, as by bridge piers, the surface of the water assumes, to a greater or less extent, the form shown in Fig. 1. As will be seen in the figure, the surface of the water is *lowest* just at the contracted section. There is a fall from a point up stream to this section, and from it, there is a rise down stream. The rise is a good deal less than the fall, so that the water above the pier is deeper than the water below, which has the same depth as before the obstruction was built.



Let Q be the quantity of water which passes any section per second.

Let d_0, d_1, and d, be respectively the depths just above the contracted section, at the contracted section, and just below it.

Let l_0, l_1, and l, be the corresponding widths.

Let v_0, v_1 and v, be the corresponding mean velocities.

Let $h = d_0 - d$

Let $x = d - d_1$

Let c = coefficient of contraction.

For simplicity, we will consider the sections as rectangular, and the bottom as horizontal. Then

$$Q = l\,d\,v = c\,l_1 d_1 v_1 = l\,d_0 v_0$$

The water at B, moving with a velocity v_1, suddenly strikes the water at C, moving with velocity v. Its impulse is,

$$\frac{wQ}{g}(v_1 - v),$$

w being the weight of a cubic foot of water. This impulse is balanced by the static pressure due to the difference in depth at the two sections, B and C. This static pressure is equal to the difference between the total pressure on the section C, and the total pressure on the section B, or it equals,

$$\frac{1}{2} w\,l\,d^2 - \frac{1}{2} w\,l\,d_1^2$$

which becomes,

$$\frac{1}{2}\, wl\,(d^2 - d_1^2).$$

Equating these two expressions, we have,

$$\frac{wQ}{g}(v_1 - v) = \frac{1}{2} w\,l\,(d^2 - d_1^2)$$

or,

$$\frac{2}{l}\,\frac{Q}{g}(v_1 - v) = (d^2 - d_1^2) \tag{1}$$

Referring to Fig. 2,

Let X and Y be two consecutive sections of any stream.

Let i be the inclination of the surface to the horizontal.

Let v and $v + dv$ be the respective mean velocities.

Let h and $h + dh$ be the respective depths, where dh is negative.

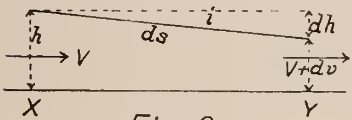


Fig. 2.

Then neglecting friction, the water in moving from X to Y is acted upon by the force of gravity which produces a uniform acceleration, $f = g \sin i$.

Now,

$$f = \frac{dv}{dt}$$

hence,

$$\frac{dv}{dt} = g \sin i$$

and multiplying both members by ds, we have,

$$\frac{ds}{dt}\,dv = g \sin i\, ds$$

$$\frac{ds}{dt} = v, \text{ and } ds \sin i = dh$$

hence,

$$dh = \frac{v\,dv}{g}$$

Integrate this between the limits, $v = v_0$ and $v = v_1$, and we have

$$h_1 = \frac{v_1^2}{2g} - \frac{v_0^2}{2g}$$

or, using the notation of Fig. 1,

$$\frac{v_1^2}{2g} - \frac{v_0^2}{2g} = (d_0 - d_1) \tag{2}$$

Since

$$Q = ldv = l_1 d_1 v_1 = l d_0 v_0,$$

(1) becomes
$$\frac{2\,dv^2}{g}\left(\frac{ld}{cl_1d_1}-1\right)=d^2-d_1^2$$

or,
$$\frac{2\,dv^2}{g}\left(\frac{ld-cl_1d_1}{cl_1d_1}\right)=(d-d_1)(d+d_1)$$

Since $x=(d-d_1)$,
$$x=\frac{2\,v^2}{g}\cdot\frac{d\,(ld-cl_1d_1)}{cl_1d_1\,(d+d_1)}$$

or,
$$x=\frac{2\,v^2}{g}\cdot\frac{(d_1+x)\;(ld_1+lx-cl_1d_1)}{cl_1d_1\;(2\,d_1+x)}$$

Now x will necessarily be very small in comparison with d_1. Therefore, we can drop it whenever it occurs in the second member, and the expression then becomes,
$$x=\frac{2\,v^2}{g}\cdot\frac{d_1^2\;(l-cl_1)}{2\,cl_1d_1^2}$$

or,
$$x=\frac{v^2}{g}\cdot\frac{(l-cl_1)}{cl_1}$$

Now referring to equation (2), since $d_1=d-x$, we have
$$d_0=d-\frac{v^2}{g}\cdot\frac{(l-cl_1)}{cl_1}+\frac{v_1^2}{2g}-\frac{v_0^2}{2g}$$

or,
$$h=d_0-d=\frac{v^2l^2d^2}{2\,gc^2l_1^2d_1^2}-\frac{v^2d^2}{2g\,(d+h)^2}-\frac{v^2\,(l-cl_1)}{gcl_1}$$

or,
$$h=\frac{Q^2}{2g}\left(\frac{1}{c^2l_1^2d_1^2}-\frac{1}{l^2(d+h)^2}-\frac{2\,(l-cl_1)}{cl_1l^2d^2}\right) \qquad (3)$$

from which formula we can calculate h, since Q, l, c, l_1 and d are regarded as known.

By first finding the value of x, or the third term in equation (3), and subtracting it from d, we obtain d_1. Then by neglecting h in the second member, we can solve the equation, and thus obtain an approximate value. By substituting this value in the second member and solving, we will obtain a still more correct result, and after a few trials, can find the precise value that will satisfy the equation.

If we desire only a rough approximation, the above equation (3) may be much simplified. Thus, dropping the 3rd term in the second member,
$$h=\frac{Q^2}{2g}\left(\frac{1}{c^2l_1^2d^2}-\frac{1}{l^2(d+h)^2}\right) \qquad (4)$$

also, by neglecting h in the 2nd term,

$$h = \frac{Q^2}{2g}\left(\frac{1}{c^2 l_1{}^2 d^2} - \frac{1}{l^2 d^2}\right),$$

or,

$$h = \frac{Q^2}{2\,gd^2}\left(\frac{l^2 - c^2 l_1{}^2}{c^2 l_1{}^2 l^2}\right) \tag{5}$$

or when $c = 1$,

$$h = \frac{Q^2}{2\,gd^2}\left(\frac{l^2 - l_1{}^2}{l^2 l_1{}^2}\right) \tag{6}$$

D'Aubuisson, in his hydraulics, translated by Bennet, uses the above formula (4) for calculating h. He gives some observations at the bridge of Minden, upon the Weser, which were reported by Funk, in 1804. Very exact measurements were made at eight different stages of the water. D'Aubuisson adds as a ninth observation the relative measurements of the extraordinary freshet of 1799. Below are given the observations in our notation, together with the heights of the backwater as calculated by him.

Q	l_1	d	c	h by Observation.	h by Calculation.
cu. ft. per second.	feet.	feet.		feet.	feet.
2048	241.8	4.68	.90	.1640	.053
15256	310.4	8.25	.90	.686	.739
27511	290.4	12.73	.90	.856	.876
28853	299.6	12.14	.90	.971	.991
29958	299.6	11.00	.90	1.030	1.060
35175	320.2	14.57	.81	1.132	1.122
39660	311.0	16.11	.81	1.237	1.257
46546	315.0	17.62	.81	1.231	1.398
83700	434.4	18.43	.81	1.772	1.834

More or less uncertainty existed as to the value of c, owing to the different forms of cutwater used, shape of piers, etc. Since, in the above data, the respective values of l are not given, the writer was unable to verify these calculations of D'Aubuisson. However, judging by the values obtained by him, it appears that formula (4) gives very satisfactory results.

In order to test the accuracy of formula (3), we will make use of the following observations given in a paper, by A. C. Howden, entitled "Floods in the Nerbudda Valley," published in the Proceedings of Inst. C. E., Vol. XXVII.:

Name of River.	Date of Flood.	Height above Datum	Fall per Mile	Area.	Hydraulic Mean Depth.	Discharge.
		feet.	feet.	sq. feet.	inches.	cu. ft. per sec.
Gungal	Aug. 8, 1866	95.00	3.00	22032	474.6	477820
Towah	" 15, 1864	101.3	4.25	29390	318.2	———

We will first consider the Towah River. The Towah viaduct originally consisted of eleven spans of 74 feet each. There were ten piers each 11 feet wide, and two abutments. On Aug. 15th, 1864, the river rose very high, and washed away piers 6 and 7. In Aug., 1865, the river rose again to the same height, and at this time, observations were taken as to the height of backwater, etc. Figures 3 and 4 show the side elevations of piers 8 and 9, as they were then determined. We have the following data:—

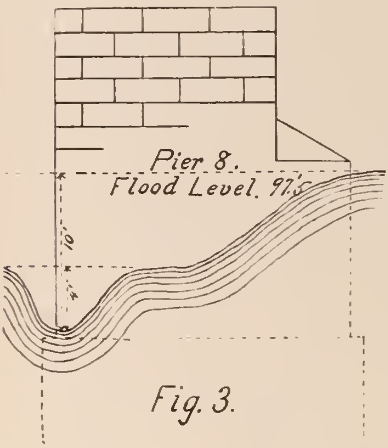


Fig. 3.

Width=830 feet.

Depth of water=37 feet.

Space occupied by piers=88 feet.

In the notation of formula (3),

l=830 feet.

d=37 feet.

l_1=740 feet.

Q=555500 cubic ft. per sec.

c=.80.

$c_1 \, l_1$=595 feet.

To obtain Q we must first find v. We have the formula for velocity,

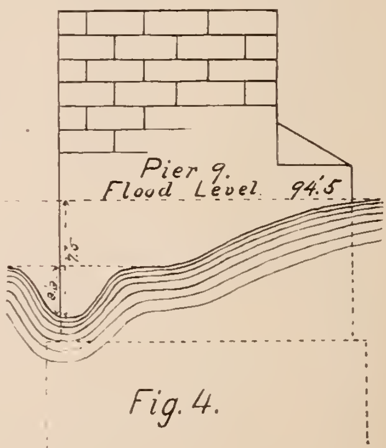


Fig. 4.

$$v = c\sqrt{ri}$$

$$r = 26.5 \text{ feet.}$$

$$i = \frac{4.25}{5280} = .0008$$

In Kutter's formula, using a coefficient of roughness, $n = .020$, we find $c = 130$;

hence, $$v = 130\sqrt{26.5 \times .0008} = 18.9$$

and $$Q = 29390 \times 18.9 = 555500.$$

We now have formula (3),

$$h = \frac{Q^2}{2g}\left(\frac{1}{c^2 l_1^2 d_1^2} - \frac{1}{l^2(d+h)^2} - \frac{2(l - cl_1)}{cl^1 l^2 d^2}\right)$$

We will first calculate the rise below the pier, which is the third term in the above formula;

we have $$x = \frac{Q^2}{g} \frac{(l - cl_1)}{cl_1 l^2 d^2}$$

or, $$x = \frac{(555500)^2 \times 235}{32.2 \times 595 \times (830)^2 \times (37)^2}$$

$2\ log\ 555500 = 11.48936$
$log\ 235 = 2.37107$
(a.c.) $log\ 32.2 = 8.49214-10$
(a.c.) $log\ 595 = 7.22548-10$
(a.c.) $2\ log\ 830 = 4.16184-10$
(a.c.) $2\ log\ 37 = 6.86360-10$
$log\ x = 40.60349-40$
$x = 4.01$ feet.

Now, $$h = \frac{Q^2}{2g}\left(\frac{1}{c^2 l_1^2 d_1^2} - \frac{1}{l^2(d+h)^2}\right) - 4$$

$$d_1 = 37 - 4 = 33 \text{ feet.}$$

Neglecting h in the 2nd member, we have,

$$h = \frac{(555500)^2}{64.4}\left(\frac{1}{(595)^2(33)^2} - \frac{1}{(830)^2(37)^2}\right) - 4$$

or, $$h = \frac{(555500)^2}{64.4}\left(.000000002594 - .000000001060\right) - 4$$

$$h = \frac{(555500)^2}{64.4}\left(.000000001534\right) - 4$$

$2\ log\ 555500 = 11.48936$
(a.c.) $log\ 64.4 = 8.19111-10$
$log .000000001534 = 1.18583-10$
$log = 20.86630-20$

Natural number $= 7.4$

hence, $$h = 7.4 - 4 = 3.4 \text{ feet.}$$

For the next approximation, assume $h = 5.0$ feet. Then,

$$h = \frac{(555500)^2}{64.4}\left(\frac{1}{(595)^2(33)^2} - \frac{1}{(830)^2(42)^2}\right) - 4$$

$$h = \frac{(555500)^2}{64.4}\left(.000000002594 - .000000000823\right) - 4$$

$$h = \frac{(555500)^2}{64.4}\left(.000000001771\right) - 4$$

$$2 \log 555500 = 11.48936$$
$$(\text{a.c.}) \log 64.4 = 8.19111-10$$
$$\log .000000001771 = 1.24822-10$$

$$\log = 20.92869-20$$

Natural number $= 8.5$

hence, $h = 8.5 - 4 = 4.5$ feet, which is near enough to the assumed value not to require a recalculation.

We can now make the following comparison:

Values of h and x at Towah River viaduct, flood of Aug., 1865:

	Calculated.	Observed.	
		at Pier 8.	at Pier 9.
	feet.	feet.	feet.
x	4.01	4	3.3
h	8.5—4.=4.5	10—4=6	7.5—3.3=4.2

Since the bed is by no means rectangular, and the depth assumed is only the mean average depth, these calculations agree as closely with observation as could reasonably be expected.

To further test formula (3), let us consider the Gungal River.

Gungal viaduct:

Width $= 650$ feet.

Depth $= 35$ feet. Waterway $= 650 - 72 = 578$ feet.

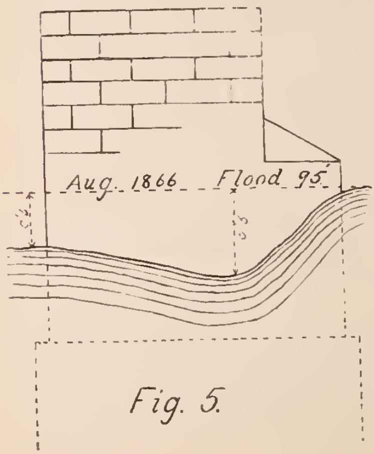


Fig. 5.

Fig. 5 shows the side elevation of the middle pier at the time of the flood of Aug., 1866. We have then—

$l = 650$ feet.
$d = 35$ feet.
$l_1 = 580$ feet.
$c_1 l_1 = .95 \times 580 = 550$ feet.
$Q = 477820$ cubic ft. per sec.

Therefore,

$$x = \frac{(477820)^2 \times 100}{32.2 \times 550 \times (650)^2 \times (35)^2}$$

$$
\begin{aligned}
2\ log\ 477820 &= 11.35854 \\
log\ 100 &= 2.00000 \\
\text{(a.c.)}\ log\ 32.2 &= 8.49214-10 \\
\text{(a.c.)}\ log\ 550 &= 7.25964-10 \\
\text{(a.c.)}\ 2\ log\ 650 &= 4.37418-10 \\
\text{(a.c.)}\ 2\ log\ 35 &= 6.91186-10 \\
\hline
log\ x &= 40.39636-40
\end{aligned}
$$

$$x = 2.5 \text{ feet.}$$

$$d_1 = 35 - 2.5 = 32.5 \text{ feet.}$$

Neglecting h in the 2nd member, we have,

$$h = \frac{(477820)^2}{64.4}\left(\frac{1}{(550)^2\ (33)^2} - \frac{1}{(650)^2(35)^2}\right) - 2.5$$

$$h = \frac{(477820)^2}{64.4}\left(.000000003036 - .000000001932\right) - 2.5$$

$$h = \frac{(477820)^2}{64.4}\left(.000000001104\right) - 2.5$$

$$
\begin{aligned}
2\ log\ 477820 &= 11.35854 \\
\text{(a.c.)}\ log\ 64.4 &= 8.19111-10 \\
log\ .000000001104 &= 1.04297-10 \\
\hline
log &= 20.59262-20
\end{aligned}
$$

Natural number $= 3.95$

$$h = 3.95 - 2.5 = 1.5 \text{ feet.}$$

For the next approximation, assume $h = 3$ feet, and we have,

$$h = \frac{(477820)^2}{64.4}\left(.000000003130 - .000000001639\right) - 2.5$$

$$h = \frac{(477820)^2}{64.4}\left(.000000001491\right) - 2.5$$

$$
\begin{aligned}
2\ log\ 477820 &= 11.35854 \\
\text{(a.c.)}\ log\ 64.4 &= 8.19111-10 \\
log\ .000000001491 &= 1.17348-10 \\
\hline
log &= 20.72313-20
\end{aligned}
$$

Natural number $= 5.3$

$h = 5.3 - 2.5 = 2.8$ feet, which is near enough to the value assumed. Hence we have the following: Gungal River, flood of Aug., 1866.

	Calculated.	Observed.
	feet.	feet.
x	2.5	2.0
h	5.3—2.5=2.8	5.6—2.0=3.6

These do not agree quite so well as for the Towah River.

In the above formulas, more or less uncertainty always exists as to the value of c. It may have any value between .80 and 1.00 depending upon local circumstances. Hence we see the necessity, in their practical application, for building the piers in such a manner, that the section of the water flowing between them may be contracted as little as possible.

Weisbach discusses this problem also, but he proceeds in an entirely different manner. He considers the water at the upper ends of the piers to be under the same conditions as in a submerged weir; and that the discharge is composed of two portions, 1st, Q', the quantity of water flowing freely above the *under water*, and 2nd, Q'', the under water discharge.

Let Q be the total discharge.

Let l_1 be the width of the contracted area.

Let l be the width of the stream above pier.

Let d be the depth below pier, which equals the depth of the under water.

Let h be the rise, or the height to which the water is backed up.

Let k be the head due to the velocity of the approaching water.

Let $c =$ coefficient of discharge.

From the formula for flow over a weir,

$$Q' = \frac{2}{3} c l_1 \sqrt{2g} \left[(h+k)^{\frac{3}{2}} - k^{\frac{3}{2}} \right]$$

Also the under water discharge is,

$$Q'' = c l_1 d \sqrt{2g(h+k)}$$

Therefore,

$$Q = Q' + Q'' = c l_1 \sqrt{2g} \left(\frac{2}{3} \left[(h+k)^{\frac{3}{2}} - k^{\frac{3}{2}} \right] + d(h+k)^{\frac{1}{2}} \right) \qquad (7)$$

which is Weisbach's formula. To find the width l_1, in order to produce the rise h, we substitute in this formula, and solve for l_1.

To get this formula in a form for calculating h, when the other quantities are known, we proceed as follows: Since $k^{\frac{3}{2}}$ is small in comparison with $(h+k)^{\frac{3}{2}}$, we can drop it in the first term of the 2nd member of the above equation, and we have

$$Q = c l_1 \sqrt{2g\,(h+k)}\left(\frac{2}{3}\,(h+k)+d\right)$$

or,

$$h = \frac{3}{2}\left(\frac{Q}{c\,l_1\sqrt{2g\,(h+k)}} - d\right) - k \qquad (8)$$

where

$$k = \frac{v^2}{2g} = \frac{Q^2}{2g\,l^2 d^2}$$

This equation can best be solved by trial.

To test the above equation, let us take the data for the Towah River.

$Q =$ 555500 cubic feet per second.
$l =$ 830 feet.
$d =$ 37 feet.
$l_1 =$ 740 feet.
$c =$ .80.
$c\,l_1 =$ 595 feet.

Then

$$v = \frac{Q}{l\,d} = \frac{555500}{830 \times 37} = 18.1,$$

$$k = \frac{v^2}{2g} = \frac{(18.1)^2}{64.4} = 5.1 \text{ feet.}$$

Now neglecting h in the second member, we have,

$$h = \frac{3}{2}\left(\frac{555500}{595\sqrt{64.4 \times 5.1}} - 37\right) - 5.1$$

$$h = \frac{3}{2}(52 - 37) - 5.1$$

or,

$$h = 17.4 \text{ feet.}$$

This value is evidently a great deal too large, and is due to the fact that h was considered zero in the 2nd member. Now assume $h = 3$, then $(h+k) = 8.1$, and

$$h = \frac{3}{2}\left(\frac{555500}{595\sqrt{64.4 \times 8.1}} - 37\right) - 5.1$$

$$h = \frac{3}{2}(41.0 - 37) - 5.1$$

$$h = 6 - 5.1 = .9 \text{ feet.}$$

From this, we see that the value assumed for h was too large. Therefore assume $h = 2.5$ feet. Then

$$(h+k) = 2.5 + 5.1 = 7.6, \text{ and}$$

$$h = \frac{3}{2}\left(\frac{555500}{595\sqrt{64.4 \times 7.6}} - 37\right) - 5.1$$

$$h = \frac{3}{2}(42.2 - 37) - 5.1$$

$$h = \frac{3}{2}(5.2) - 5.1$$

$$h = 7.8 - 5.1 = 2.7 \text{ feet.}$$

which is near enough to the assumed value not to necessitate a recalculation.

As previously stated, the observed value of h was from 4 to 6 feet, so that this formula does not agree with observation near so well as formula (3). However, since in its deduction, k was assumed to be very small as compared with $(h+k)$, and in the above example, this is not the case, we could not expect it to give a very accurate result.

Formula (2) can be applied to determining the rise caused by any contraction whatever in the cross-section of the stream, independent of the form and character of the obstruction which produces the contraction. In other words, whether the obstruction be a pier, a jetty, submerged or otherwise, or a submerged dam, formula (2) can be applied in each case, to give approximate values of the heights to which the water will back up. For example, we have

$$h = \frac{v'^2}{2g} - \frac{v'_0{}^2}{2g} \qquad (2)$$

Let A_0 = area of section of stream above the obstruction.
Let A = " contracted section of stream.
Let v_0 and v be the respective velocities.

Then we have

$$v_0 A_0 = c\, v\, A$$

or,

$$v = v_0 \frac{A_0}{cA}$$

and (2) becomes

$$h = \frac{v_0^2}{2g}\left(\frac{A_0^2}{c^2 A^2} - 1\right) \qquad (9)$$

In Jackson's Hydraulic Manual, page 106, the following formula for calculating h may be found. This formula is the one proposed by Dubuat, and is,

$$h = \left(\frac{V^2}{2g\,c^2} - s\right)\left\{\left(\frac{A}{a}\right)^2 - 1\right\}$$

where A and a are the normal and reduced sectional areas of flow, s is the sine of the hydraulic slope of the river, and o the experimental coefficient of discharge. Neglecting s, which is the term representing the friction, this becomes

$$h = \frac{V^2}{2 g o^2}\left(\frac{A^2}{a^2} - 1\right)$$

which is practically the same as formula (9) given above.

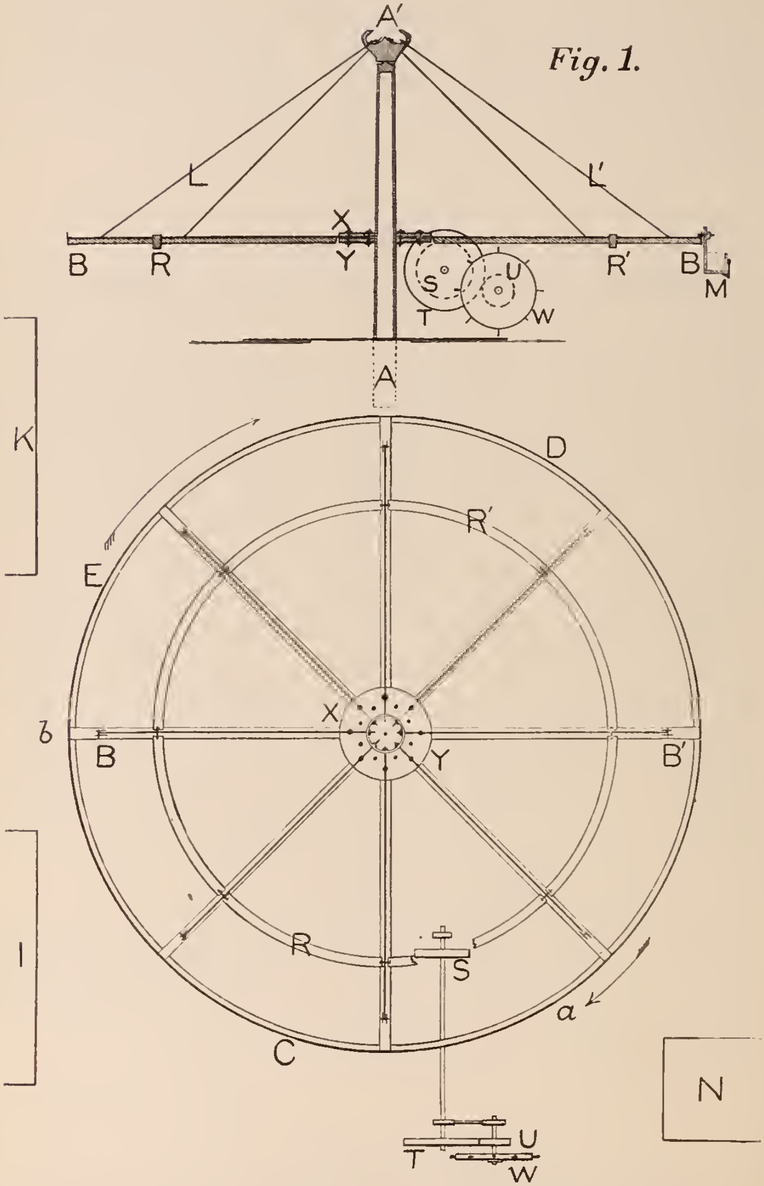
On page 279*f* of Trautwine's Pocket Book is given a table taken from Nicholson's Architecture. It gives the head of water produced at the obstruction, in feet, for various velocities from 0.25 feet to 10 feet per second, and for different ratios of contraction from one-twelfth to three-quarters. It supposes the piers to be properly rounded or pointed at their up-stream ends, so as to give as free a passage to the water as possible. The values of h are carried out to *four decimal places.* By substituting in formula (9) the different values of $\frac{A_o}{A}$, and comparing the results obtained with those given in the table, we find that there is quite a difference in the two sets of values, and also that this difference does not seem to follow any definite law. From this, and from the explanatory foot note given by Trautwine, it is clearly evident that the table is a very rough approximation, and that in any particular case, it would be far safer to apply a reliable formula. In fact, no satisfactory tables could be constructed for this purpose on account of the great uncertainty in the data, and the ever varying conditions of the problem.

In conclusion, it should be stated that no satisfactory comparison between theory and observation can be made, until a widely extended series of reliable experiments can be obtained, and considering the practical importance of the subject, such observations should be begun as soon as possible.

SAMUEL W. FRESCOLN.

SLAG BRICK.

The process of making paving brick from furnace slag is of but recent origin. That bricks could be made was not difficult to show, but how to make them in order to withstand the wear and tear of traffic, and to compete in quality and price, with other materials for paving, is what demands the attention of those interested at the present time.



To throw some light on the subject of Slag Brick, the following notes are submitted:—

The Machine. The machine which we are about to describe, has been in operation at the Glendon Iron Works, Glendon, Pa., and was patented June 17, 1884. It was first brought out by

a Mr. Dobbs in England, and brought by his son, Mr. Henry Dobbs, to the United States, who had the machine in question under his immediate supervision. It is now operated by the Scoria Manufacturing Co., New York City.

The machine consists of an upright post *A* (see Fig. 1) made of cast-iron, about 12 feet high and 8 inches diameter, set in the ground. Two feet from the ground and concentric with the post, are two plates, *X* and *Y*, 10 inches diameter, 1 ¼ inches thick and ½ inch apart. From between these plates, run radiating arms *BB′*, etc., made of tee irons, 12 feet × 5 inches × 2⅜ inches. A 3-inch angle, bent circular and rivetted to the ends of the arms, forms the circumference of the machine, *C D E*. To this circumference are attached the moulds *M* (only one shown) for the bricks. Fig. 2 shows a mould drawn to larger scale. They number 141, consisting of the following sizes. All are 6 inches deep and 3 ½ inches wide, but vary in length:

135 are 8 inches long,
4 are 12 inches long and
2 are 4 inches long.

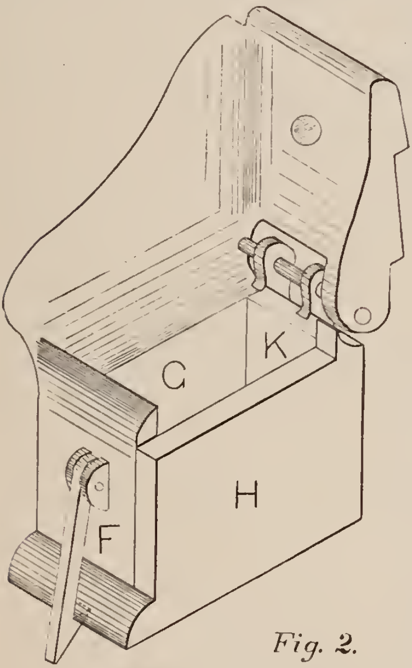


Fig. 2.

These boxes are made up of two parts: one of which, bolted to the circumference of the machine, is made up of two sides of the box *F* and *G*. The other part, consisting of *H*, *K*, and the bottom, swings on hinges so that it can be brought up and hooked to the first part, thus forming the complete five-sided mould.

The *bottom* of this box forms the top of the brick. Sixteen inches within the circumference, and attached to the arms and the swinging head *A* of the post, are 1-inch round iron braces *L*, *L′*, etc. The rotation is accomplished as follows: 3 feet 4 inches within the circumference and concentric with the post, is a circular rack 3 inches × 3 inches, *RR′*. Running in this rack is a bevel gear-wheel *S*, 26 inches diameter; to the shaft of this gear-wheel is attached another *T*, 36 in. diameter, 2 ¼ in. wide. This is rotated

by a pinion *U*, 14 in. diam. To the shaft of this pinion is attached a hand wheel *W*, 36 inches diameter, where the power is applied.

The Process. The process may be briefly stated as follows: The slag runs from the furnace to a box *N*, 4 feet × 4 feet × 4 feet, and from this by a V shaped trough into the moulds at *a*. As they fill up, the machine is rotated in the direction of the arrow, and after revolving $\frac{\pi d}{4}$, the hook is drawn at *b* and the bricks drop out. At this stage, the bricks are black in color, and are chilled from a sixteenth to an eighth of an inch, as they afterward show, which is sufficient to allow of their being handled without altering their shape. They are picked up and piled into ovens, *K* and *I*, whose capacity is from 500 to 600. As the ovens fill, the bricks become white hot *by their own heat.* The doors are shut, the cracks and holes are stopped with mud, excluding the air, and the whole is left to cool. In the machine at the works of the Thomas Iron Co. at Catasauqua, Pa., the bricks are thrown into a pit and are then covered with ashes, etc., and left to cool.

Conclusions. The object in making the brick 3½ inches wide is to allow for a foot-hold for the horse's shoe. To further assist, the top edges are beveled ½-inch. as shown in Fig. 3. The sizes 4 inches and 12 inches, are to break joints.

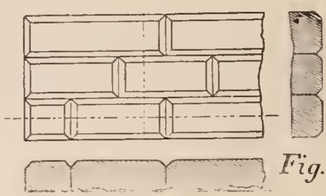


Fig. 3.

The *cost* of producing these brick may be obtained thus: the capacity of a kiln may be taken at an average of 550. Four kilns can be filled in a shift of 12 hours. To work the machine, requires a force of 8 men and 2 boys, at $1.50 and $0.90 per day of 12 hours, respectively.

$$550 \times 4 = 2200$$

$$\$1.50 \times 8 + \$0.90 \times 2 = \$13.80.$$

Allowing 10 % for imperfect ones and loss by sticking, we get

	Cost per M =	$6.90
	" " sq. yd. =	.31
They have been sold at	per M. =	$50.00
	per sq. yd. =	2.31
The primes are offered at per	M. =	40.00
	" sq. yd. =	1.85
The seconds at	" M. =	30.00
	" sq. yd. =	1.39

A selected specimen at hand,

(small size, 4 inches × 6 inches × 3½ inches) weighs 8¼ lbs. The next size, 3½ inches × 6 inches × 8 inches, from 13 to 17 lbs.

The cost at market is then increased by the cost of transportation. Taking the weight of a medium size at 15 lbs., and the freight per ton net at $1.50 for 100 miles, the cost is then,

$$\text{Per M} = \$40.00 + 11.25 = \$51.25$$
$$\text{" sq.yd.} = \quad 1.85 + 0.43 = \quad 2.28$$

The quality of the brick depends upon the kind of iron cast. When running "No. 2" and "Gray Forge," the slag will be homogeneous and compact, and will make the best brick. "Mottled" and "White" produce the next best slag. "No. 1" makes the brick puffy and porous. So that, when running hard iron the slag will be darker, and when darker, there is less liability of sticking together in the ovens; while with the lighter shades, there is great loss caused by sticking. The quality is also dependent upon the heat of the furnace; too high a heat makes a soft brick; a moderate heat gives the best results.

As slag brick have not been in use for any extended period, nothing definite can be said of them. They are laid in the same manner as other forms of paving stones, sometimes with sand, and again with rubble foundation and cement. The thin outer shell being brittle, the bricks are nicked, but do not suffer by it. When broken, they show a structure and color not unlike blue limestone for the Glendon and Catasauqua specimens, and not unlike very compact sandstone for some of the Glendon specimens. The poorer qualities are marked by their inferior weight and tendency to crack. They are not very noisy, and can be easily cleaned from dirt and ice. They do not materially absorb any water, and hence are not injurious from sanitary considerations.

Porosity. A selected brick (small size) was tested for porosity as follows:—

In oven at normal temperature, - - 48 hours.
In air, - - - - - - - 48 hours.
When under water, - - - - 24 hours,

it showed 0.0955 % of its weight of water absorbed.

When under water - - - - 48 hours,

there was no increase, showing that saturation was complete before the second immersion. When left under water for a length of time, they show signs of cracking in all directions. The weather has no perceptible effect upon them.

The Glendon bricks are only for street pavements. Those made at

Catasauqua are of two sizes. One size, 10 inches × 5 ¼ inches × 5 inches is for street pavements; they have three groves on the top to prevent slipping. The other size, 10½ inches × 10½ inches × 1 ¼ inches, is for sidewalks. These have circular grooves, also to prevent slipping. *When properly laid, they will not break nor tip up.* A specimen of the street pavement can be seen at corner Lehigh and Canal Streets, in front of the Lehigh Valley Railroad Station, in South Easton, Pa.; of the sidewalk, opposite lower Lehigh Valley Railroad Station, South Easton, and corner of Nesquehoning Street and Old Philadelphia Road; in Easton, corner Sixth and Northampton Streets, and in many places in Bethlehem and South Bethlehem. The Jordan Bridge in Allentown, Pa., is laid with Catasauqua brick, and they show considerable wear from abrasion, but between the car tracks they are remarkably well preserved.

The *Specific Gravity*, I have found to be as follows:

Glendon Primes, - - - -	2.90
Glendon Seconds, - - - -	2.73
Catasauqua (street) - - - -	2.89
Catasauqua (sidewalk) - - - -	2.57
Common Slag, - - - -	2.42 to 2.45

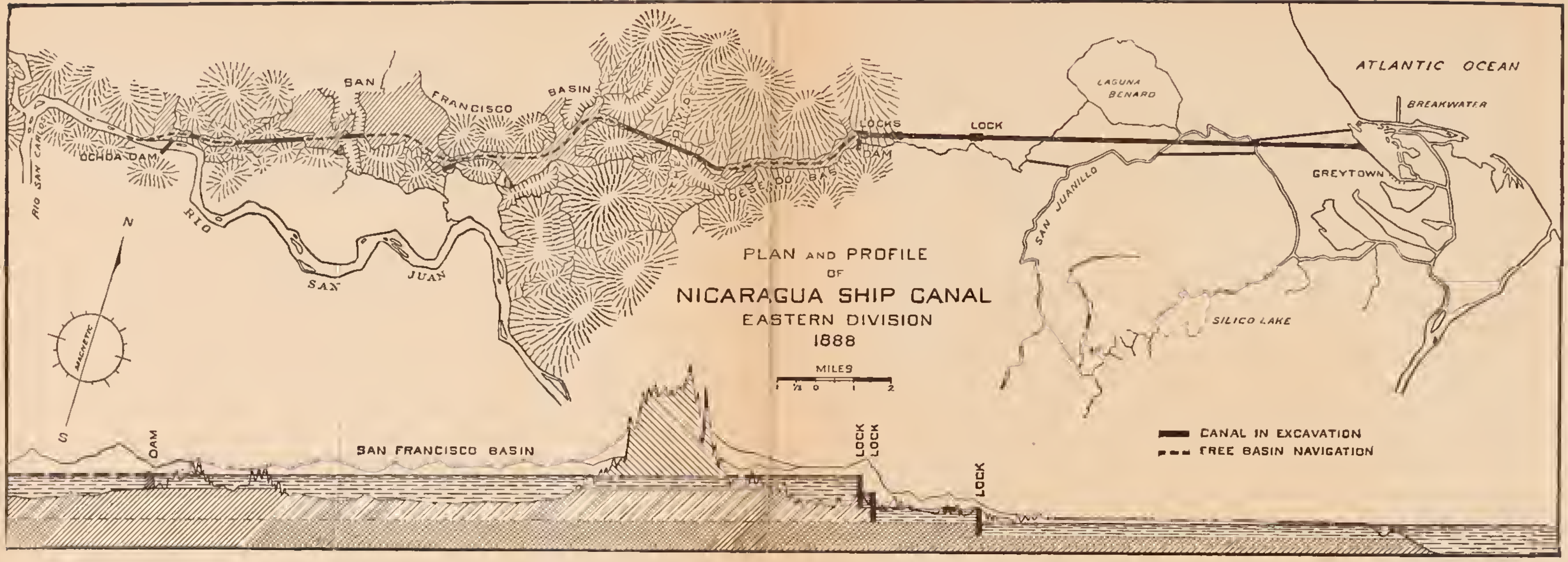
In a correspondence with the Scoria Manufacturing Co. of New York, in regard to the strength of the Glendon brick, they say:—

* * * * * * "The only test I know of, was made by some one interested with the Schloss Furnaces, and he reported the resistance as 140,000 lbs. (70 net tons.) This, I am inclined to doubt. There is no doubt, however, in my own mind, that it is 5 times as great as Granite." * * * * * *

There have been a number of the pavements put down, but so recently that it is impossible to judge definitely of their relative merits. There is no doubt but that the quality of the slag *may* be improved by some intermediate or supplementary process, which combined with the low cost of material and improved machinery, may result in producing a brick combining all the requisites of a good paving material.

I take this means of acknowledging my indebtedness to Mr. Charles K. Thomas of the Glendon Iron Works, who has furnished me with many important details in the process, and has rendered assistance in acquiring the above data.

J. B. Wright, '89.



ALONG
THE
NICARAGUA CANAL.

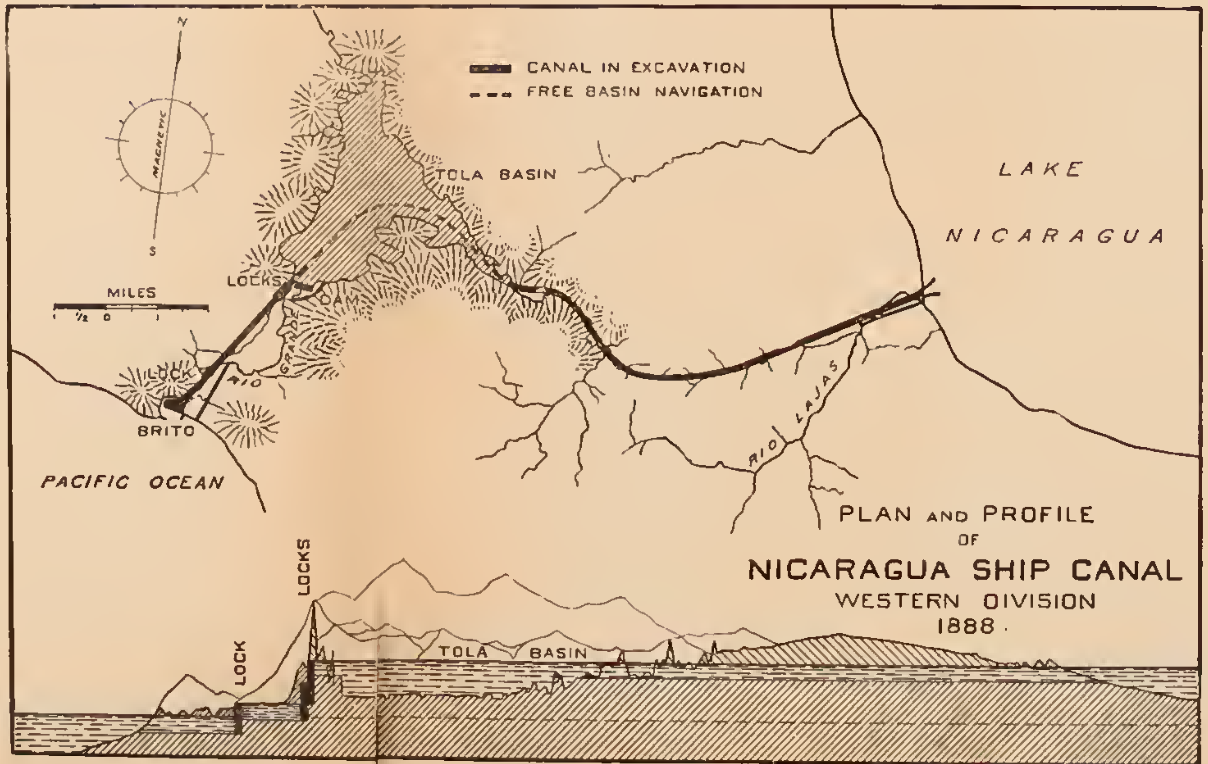


TABLE SHOWING DISTANCES IN MILES BETWEEN COMMERCIAL POINTS OF THE WORLD, AND DISTANCE SAVED BY NICARAGUA CANAL.

From		Via Cape Horn.	Via Cape of Good Hope.	Via Nicaragua Canal.	Distance Saved.
New York to	San Francisco...	14,840	....	4,760	10,080
"	Behring Strait...	16,100	....	7,882	8,218
"	Alaska............	15,300	....	6,682	8,618
"	Acapulco.........	13,071	....	3,122	9,949
"	Mazatlan.........	13,631	....	3,682	9,949
"	Hong Kong......	18,180	15,201	11,038	4,163
"	Yokohama.......	17,679	16,190	9,363	6,827
"	Melbourne........	13,502	13,290	10,000	3,290
"	New Zealand....	12,550	14,125	8,680	5,445
"	Sandwich Isl'ds	14,230	....	6,388	7,842
"	Callao.............	10,689	....	3,713	6,976
"	Guayaquil........	11,471	....	3,053	8,418
"	Valparaiso........	9,750	....	4,700	5,050
New Orleans to	San Francisco	15,052	....	4,047	11,005
"	Acapulco.........	13,283	....	2,409	10,874
"	Mazatlan.........	13,843	....	2,969	10,874
"	Guayaquil........	11,683	....	2,340	9,343
"	Callao.............	10,901	....	3,000	7,901
"	Valparaiso........	9,962	....	3,987	5,975
Liverpool to	San Francisco...	14,690	....	7,508	7,182
"	Acapulco.........	12,921	....	5,870	7,051
"	Mazatlan.........	13,481	....	6,430	7,051
"	Melbourne........	13,352	13,140	12,748	392
"	New Zealand.....	12,400	13,975	11,349	1,051
"	Hong Kong......	18,030	15,051	13,786	1,265
"	Yokohama..... ..	17,529	16,040	12,111	3,929
"	Guayaquil........	11,321	....	5,890	5,431
"	Callao.............	10,539	....	6,461	4,078
"	Valparaiso........	9,600	....	7,448	2,152
"	Sandwich Isl'ds	14,080	....	9,136	4,944
Spain to	Manilla...............	16,900	13,951	13,520	431
France to	Tonquin.............	17,750	15,201	13,887	1,314
Hamburg to	Mazatlan.........	13,931	....	6,880	7,051
"	Acapulco.........	13,371	....	6,320	7,051
"	Fonseca...........	11,430	....	5,530	5,900
"	Punta Arenas... (Costa Rica)	11,120	....	5,515	5,605

NOTE.—Distances have been measured by routes most convenient for sailing ships and slow freight steamers only. For this reason distances via Suez Canal do not appear in the table.

[The above table was taken from a chart published by the Maritime Canal Co. of Nicaragua.—EDS.]

ALONG THE LINE OF THE NICARAGUA SHIP CANAL.

On the 10th of December, 1887, the Steamship "Hondo" dropped anchor just outside the harbor of Greytown, and we—that is, the expedition of 1887–88,—saw for the first time the low, sandy shore of Nicaragua.

We looked around for the town, but the only sign of habitation was a forlorn looking store-house, built on the long sand bank which closes the harbor. This obstruction has been formed by the action of the tide in conjunction with the current of the San Juan River, which, loaded with silt, empties into the Caribbean Sea at this point, and deposits its accumulation of volcanic sands in the form of a long bar.

In order to reach shore, we went aboard a small tug and were soon headed for the bar, just where the breakers seemed to be largest and roar loudest. As we drew nearer to the line of surf, we saw an opening where the waters appeared less agitated, and were about to slip through on the crest of a huge wave, when—thump! we were let down on the bar, as if the waves wished to emphasize the fact that this was the first obstacle in the way of the Nicaraguan Canal. The succeeding wave, much to our relief, carried us into the comparatively quiet waters of the harbor.

Real estate steadily advanced in price as we approached the town, until, when we tied up at the wharf, lots were worth twice as much as when the vessel was first sighted.

Greytown is situated at the mouth of the lower San Juan, which is the most northerly branch of the San Juan proper, the other and larger branch being the Colorado, which empties into the sea, about ten miles south of Greytown. As the silt brought down by the lower San Juan is gradually filling the harbor and augmenting the sand bar, it is proposed to cut off this branch of the river, and to discharge all the water of the San Juan through the Colorado. A jetty is then to be built out from the shore, and the harbor is to be dredged out, and thus rendered serviceable. At Greytown, the line of the canal begins in the low marshy lands which characterize the delta of the San Juan. These marshes are thickly overgrown with grass, and contain numerous specimens of the black palm. The land gradually rises as we proceed westward from Greytown, and at a distance of three miles, we cross the San Juanillo, which, sweeping around a horseshoe bend, again crosses

our path, two and one-half miles further on. This river will be disposed of by digging a small canal so as to cut off the loop mentioned above, thus straightening the river and removing it from the line of the canal.

The land rises more rapidly now, and after crossing the Deseado River, which empties into Bernard Lagoon and is to be diverted into the San Juanillo by a small artificial channel, we come to the first lock. A lift of about 26 feet places us on the second level of the canal, where we find no obstacles to our progress, save the interlacing vines and dense underbrush which characterize tropical jungles. The natives go before us, and with their trusty machetes cut a path through the woods, and at the end of a three mile tramp, we pause at the site of the second lock.

This lock will have a lift of 27 feet, and its fellow, No. 3, only a mile to the west of it, raises the level of the canal 53 feet. This lock is to be carved in the solid rock, and has been the subject of much discussion.

As we stand at the beginning of this, the fourth level, we are twelve and one-half miles from Greytown, and the water in the canal will be 106 feet above mean tide. The stretch between lock No. 3 and Greytown is the most unhealthy section on the whole line, and fortunately, the marshy character of the ground admits of the work being done by dredges.

Close to this lock, is the site of a dam or embankment which is to be built across the valley of the Deseado River, thus flooding the land, and furnishing a stretch of free navigation four miles long, bringing us to the foot of a range of hills, the watershed or "divide" between the Atlantic slope and the valley of the San Juan.

As we ascend, we meet clear mountain brooks, that leap in falls down the slope, and as the cool breath of the trade wind strikes us, we laugh at malaria and fever which threatened us in the lowlands near Greytown. We are so wrapped in the beauties of this wild woodland, that we do not at first realize the great value of the water-power of these streams which dash past us. With this head of water, the surface soil can be cut away at a minimum cost, and not until we strike solid rock does the blasting begin. At this spot, Nature has greatly favored the canal route, for this section through the "divide" comprises the heaviest cutting on the whole line, and will occupy a large force of men for a long period

of time. What healthier or more favorable location could be found for a camp, than here on the hillside, with an abundance of fresh, pure water close at hand, and right in the path of the trade winds which blow away the miasmas and poisonous vapors, and bring in their place the invigorating sea breezes?

The cut through the "divide" is about 15,000 feet long, and has an average depth of 149 feet. This, however, is the deepest cut on the line.

As we descend the western slope of the "divide," we enter the valley of the San Francisco. This river is formed by the juncture of the Chanchos, which rises at the "divide" and flows westward, with the San Francisco which, rising in the northwest, flows south-east and east, and after receiving the Chanchos turns abruptly to the south and empties into the San Juan. By a series of dams and embankments, short and admirably located between rocky hills,it is proposed to flood the valleys of the Chanchos, the San Francisco, and further on, the Machado, and thus obtain eleven miles of free navigation. The only cutting to be done in these eleven miles is a section, 1.7 miles long, where the line pierces the hills which separate the valley of the San Francisco from that of the Machado.

From Greytown, our path has lain through a trackless wilderness inhabited only by strange birds and beasts, prominent among which was the red monkey, whose curious antics, as he went scampering through the trees, were highly amusing. Occasionally we came across herds of deer, and droves of wild hogs, and flocks of delicious wild turkeys were frequently met. We saw snakes, too—real ones,—but they proved to be far less annoying than the mosquitoes, the Congo flies, and à little insect bearing the high-sounding name of "garapata," but in reality a common North American wood-tick.

The Machado, as we see from the map, empties into the San Juan River, and hence that broad stream for the present checks our further progress. So we camp on shore, and wait for the river steamer.

We are now at Ochoa, the site of the great dam, perhaps the most daring element of the canal scheme. The San Juan at this point is about 1133 feet wide, and has an average depth of only 6.6 feet. The dam, measured along the crest, will extend 1255 feet, and have a height of 52 feet, backing the water of the San Juan clear to the lake, and maintaining the whole at an elevation of 110 feet, which is the highest level of the canal.

For fear the size of this dam may shake your faith in the canal scheme, we would remind you that the Vyrnwy dam at the Liverpool waterworks, is 136 feet high and 1255 feet long; the dam for the San Francisco waterworks will be 170 feet high and 700 feet long, while the much-talked-of Quaker Bridge dam will be 278 feet high and 1300 feet long, and so we might mention others, beside which the dam at Ochoa would appear dwarfed.

Before boarding the steamer, we must note carefully how the hills on each shore approach almost to the waters edge, and make the location for the dam as favorable as possible.

As we go paddling up the stream in the little stern-wheeler, we can enjoy the beauties of this majestic river, which affords the only outlet for Lake Nicaragua, and which in the 64 miles from Ochoa to the lake, receives only one important tributary, the San Carlos. A vast sheet of water like Lake Nicaragua, 90 miles long and 40 miles wide, is not subject to sudden floods, so that the San Juan as far as the dam, is free from those sudden risings which render tropical rivers so unmanageable. This, as we readily recognize, has a very important bearing on the location of the canal, for were the San Juan like its more famous and more unruly neighbor, the Chagres, it could not be utilized as a part of the canal.

Our journey as far as Castillio is uneventful, if we except occasional shots at sleeping alligators, and a tramp of a mile and a half around Machuca Rapids, in the footsteps of the gold-hunters, who came by this route in '49, on their way to California.

At Castillo, the stately San Juan breaks into a rage and comes tumbling with a roar over the rocks, which lie in its path. The steamer cannot pass these rapids, so we take another and larger steamer above the rapids, and about nightfall reach the mouth of the lake, and board the lake steamer "Victoria."

The only work required to render the San Juan serviceable as part of the canal is dredging and rock excavation to an average depth of four feet for the twenty-four miles from the lake towards Ochoa.

On board the lake steamer, we make our beds on deck, and soon fall asleep. A strong healthy breeze, playing havoc with our blankets, awakens us in the morning, and we open our eyes on a never-to-be-forgotten scene. We are far out on Lake Nicaragua, the keystone of the Nicaraguan Canal route. It is indeed a magnificent sheet of water, and at an elevation of nearly 110 feet above mean tide, it lies like an immense emerald in a huge cup, of which

the turquoise-blue Chonales Mountains form the rim. "Westward, ho!" is our motto, and as we turn our eyes hither, we see the scarred sides of Volcanic Ometepec, which springing from the very waves, rises a perfect cone 5,350 feet, and veils its head in the clouds.

We land at San Jorge, and ride to Rivas, a distance of three miles, where we remain several days. But we cannot stop long to admire this quaint old Spanish town, with its dark-eyed señoritas, and so turn our horses' heads toward the mouth of the Rio Lajas. It is at this point that we strike the line, which following up the valley of the Lajas and its tributary, the Guscoyal, crosses the low, gently sloping divide only 42 feet above the lake, and enters the deep and narrow valley of the Rio Grande. From the lake to this point, the monotony of wilderness is broken by an occasional plantain or indigo plantation, and fields of corn are also seen. For a distance of three miles, the Rio Grande winds and turns in its deep valley, with hills rising steeply from the very river-bed. Here the skill and ingenuity of the engineer has been severely tested, but he has triumphed, for when we pause at the mouth oi the Guachopilin, where the valley begins to broaden, we have not passed around a sharper turn than a one degree curve, and have kept continually in the bed of the river.

Now we are about to enter another stretch of slack-water navigation, in the flooded valley of the Rio Grande. The dam at El Dulce Nombre will back the waters of the Rio Grande, augmented by those of the Tola River, clear to the mouth of the Guachopilin. This valley, especially as we approach the town of Tola, is very fertile, and is largely under cultivation, and if we except the large plantations in the vicinity of Rivas, is the first spot where we see groves of cacao trees and coffee plantations. As we journey through this most delightful valley, we see more houses and have a better opportunity to observe the people and their many interesting peculiarities, but we will not discuss them here.

Finally we reach a spot, where the hills on either side of the valley bend around and approach each other, as if determined to head off the Rio Grande, which, however, glides smoothly along, and, calm and placid, slips past over the very feet of its enemies. This is the site of the dam at El Dulce Nombre, and really could not be surpassed. The hills on either side rise over 200 feet, and with such a steep slope that it was only with the greatest diffi-

culty that we ran the level over the cross-section lines. In fact it was this admirable location for a dam, that first suggested the idea of flooding the Tola basin.

Here, too, is the site of the fourth lock, the first one we have encountered since we left lock No. 3, at the entrance to the Deseado Basin, just 154 miles away. This, then, is the length of the summit level of the canal.

As we rest on the hillside, we hear the boom of the waves from the Pacific, for we are only three and one-half miles from Brito. This stretch is marked only by the three locks which bring us to the level of the ocean, which, we may add here, is the same for both oceans.

The last lock is a tidal lock, and is nearly two miles from the Pacific. The canal for these two miles will be greatly widened, and will practically form an extension of the harbor of Brito, which will also be much improved by two breakwaters, that are to be built out from the shore.

We pitch our tents near a small spring which furnishes the only fresh water in the neighborhood, and prepare to rest, for we have taken a long tramp. Starting from Greytown, and following the line of the canal, we have come a distance of 169 miles. In this entire distance we have but 29 miles of excavation, leaving 140 miles of free navigation. Of these 140 miles, 64 miles are obtained in the San Juan river, 57 miles in crossing Lake Nicaragua, and the remaining 19 miles in the flooded San Francisco and Tola basins.

We have not forgotten the ways of civilization during our sojourn in the wilderness, for when the conversation lags, we discuss the weather, and although each member of the party is very weather-wise, a better idea of the general climate of Nicaragua can be obtained from the very exhaustive paper on that subject, by Surgeon J. F. Bransford, U. S. N., in the "Report of the Discussion of the Nicaragua Canal, before the American Association for the Advancement of Science," in August, 1887, from which we have condensed the following:—

"In 1881, the maximum temperature was 86° F., occurring in April and May, and the minimum 69.8° F. in February, and the greatest range of temperature during any month of the year, was recorded for June as 13.9°. In the same year, the range of the thermometer at Washington was 118.3°, from 104.3° to—14°F.

In 1883, we have the maximum temperature in May 93°F., and the minimum in December, 66°. The maximum monthly mean was 84°, for the month of May, and the minimum 75° for Decem-

ber. The total amount of rainfall was 47 inches, of which 19 inches fell in October. The average yearly rainfall from 9 years' observations is 64.4 inches. Some idea of this amount of rainfall can be obtained by comparing it with the mean annual rainfall of Philadelphia, which is 44.6 inches. A traveler in a tropical country is apt to overestimate the amount of rainfall, since the greater part of the rain falls in a few months. In the present case, for the region west of Lake Nicaragua for which the above observations were recorded, the rainy season lasts from May to November, the dry season occurring during the remaining months."

From these rather brief statistics, we see that the western part of Nicaragua enjoys a much healthier climate than is generally supposed. The even temperature and the prevailing winds make the heat, which is not very great, much more endurable than even a lower mean temperature would be here in our own country, where we are subject to such sudden changes.

The country from Greytown to the lake is, as was mentioned before, an unbroken wilderness, and the dense vegetation causes a larger amount of rainfall in this region than in the country west of the lake. For this section we have no statistics, although observations were made by the last expedition.

During the three months that our party spent on the eastern side, the rain fell continually, and the dry season was just about to set in when we crossed the lake. However, in spite of the rain and the marshes, the members of the party were healthy, and in the whole expedition of over 200 men, there was not a single severe case of sickness of any kind.

What, if in our camp on the Pacific shore, we should, like Rip Van Winkle, sleep for twenty years, or even ten years, and then awakening, look about us? We are still at Brito, but instead of being alone in the wilderness, we are in the midst of a thriving city. Out in the harbor, are ships from all parts of the world. Ships from San Francisco bound for New York about to pass through the canal, and shorten their journey by 10,000 miles. Ships from Valparaiso, headed for New York, which will take the short cut and save 5000 miles. Ships laden with the teas of China, which no longer dread the storms of Cape Horn, and are nearer to New York by 4163 miles. At many a masthead floats the British flag, and vessels from Liverpool, with their bows turned towards San Francisco, have shortened their journey by 7182 miles.

We go aboard one of the many steamers bearing the American

flag, and start eastward. For the first two miles, the canal forms an extension of the harbor, and is nearly 300 feet wide. At the end of this section, we meet the first lock, a magnificent structure 650 feet long, large enough to float the "Great Eastern." We pause 45 minutes at each of the next two locks, and then go on, through the fertile Tola valley, now one vast coffee plantation, and after the canal has narrowed to 80 feet in passing through the deep valley of the upper Rio Grande and the rocky cut of the Western Divide, we enter Lake Nicaragua. All along the line, the topography of the country has changed; fields have replaced forests, and villages have grown to towns. Along the shore of the lake, stand immense dry docks, and vessels are resting in this huge fresh-water harbor, before setting out again on their long journeys,

Down the broad San Juan we steam, pause a moment and listen to the roar of the water pouring over the dam at Ochoa, and then enter the flooded valley of the San Francisco. We can hardly recognize the country here, so greatly has it changed. Wilderness and marsh have disappeared, and only large fields of plantains, bananas, and dark-green orange groves are to be seen. Once more the canal is but 80 feet wide as we pass through the deep cut of the Eastern Divide, and then it widens into the Deseado Basin, at the end of which we approach lock No. 3. Slowly the massive gates turn, and we are lowered gently 53 feet, as easily as if the distance were but 15. Passing quickly through locks 2 and 3, we reach Greytown, the Atlantic seaport, about thirty hours after leaving Brito.

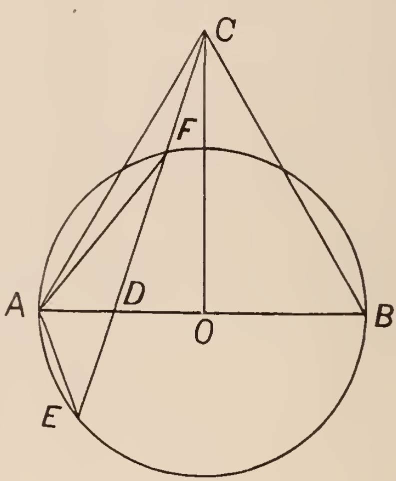
As the vessel puts out to sea, we look back, and in place of the straggling town which we saw ten years ago, we behold a mighty seaport, and as we see the Stars and Stripes fluttering at the entrance of the canal, we recall with a feeling of pardonable pride, that it is due to American energy, American perseverance, and American skill that the Nicaraguan Canal has been built.

Emil Diebitsch, '89.

GRAPHICAL CONSTRUCTION OF REGULAR POLYGONS.

Some time ago, the president of our Engineering Society stated the following graphical method of constructing a polygon of any number of sides in a given circle, and submitted the question whether it was mathematically correct. Upon any diameter of the

given circle as a base, erect an equilateral triangle, divide this diameter into as many parts as the polygon is required to have sides, join the vertex of the triangle with the second point of division counted from either end of the diameter, and prolong this line until it meets the circumference a second time; a line joining this point of intersection with that end of the diameter from which the divisions were counted then represents a side of the required polygon.



In answer to the above, the following solution is offered. Referring to the accompanying figure, let the diameter be equal to unity, and let m be the number of sides of the required polygon. Then $AB = AC = 1$ and $AD = \frac{2}{m}$. Draw AE the side of the polygon, and also AF. The angle AFD will then be measured by the arc AE, and if this graphical method is mathematically true, the angle AFD must be equal to $\frac{\pi}{m}$.

AD being equal to $\frac{2}{m}$, we have

$$DO = \frac{1}{2} - \frac{2}{m} = \frac{m-4}{2m}$$

$$\overline{CO}^2 = 1 - \left(\frac{1}{2}\right)^2 = \frac{3}{4}$$

$$\text{then } CO = \sqrt{\frac{3}{4}} = \frac{1}{2}\sqrt{3}$$

$$\overline{CD}^2 = \overline{DO}^2 + \overline{CO}^2 = \left(\frac{m-4}{2m}\right)^2 + \frac{3}{4} = \frac{m^2 - 2m + 4}{m^2}$$

$$\text{and } CD = \frac{1}{m}\left(m^2 - 2m + 4\right)^{\frac{1}{2}}$$

$$Cos\ DCO = \frac{CO}{DC} = \frac{\frac{1}{2}\sqrt{3}}{\frac{1}{m}(m^2 - 2m + 4)^{\frac{1}{2}}} = \frac{m}{2}\left(\frac{3}{m^2 - 2m + 4}\right)^{\frac{1}{2}}$$

$$Sin\ D\,C\,O = \frac{D\,O}{D\,C} = \frac{\frac{1}{2} - \frac{1}{2}}{\frac{1}{m}(m^2 - 2m + 4)^{\frac{1}{2}}} = \frac{m-4}{2(m^2 - 2m + 4)^{\frac{1}{2}}}$$

$$Cos\ A\,C\,O = \frac{O\,C}{A\,C} = \sqrt{\frac{3}{4}} = \frac{1}{2}\sqrt{3}$$

$$Sin\ A\,C\,O = \frac{A\,O}{A\,C} = \frac{1}{2}$$

$$Cos\ A\,C\,D = Cos\,(A\,C\,O - D\,C\,O)$$

$$= Cos\ A\,C\,O\ cos\ D\,C\,O + sin\ A\,C\,O\ sin\ D\,C\,O$$

$$= \frac{1}{2}\sqrt{3} \cdot \frac{m}{2}\left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} + \frac{1}{2} \cdot \frac{m-4}{2(m^2 - 2\,m + 4)^{\frac{1}{2}}}$$

$$= \frac{3}{4}m\left(\frac{1}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} + \frac{1}{4}m\left(\frac{1}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} - \left(\frac{1}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}}$$

$$= \frac{m-1}{(m^2 - 2\,m + 4)^{\frac{1}{2}}}$$

$$Sin\ A\,C\,D = sin\ (A\,C\,O - D\,C\,O)$$

$$= sin\ A\,C\,O\ cos\ D\,C\,O - cos\ A\,C\,O\ sin\ D\,C\,O$$

$$= \frac{1}{2} \cdot \frac{m}{2}\left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} - \frac{1}{2}\sqrt{3} \cdot \frac{m-4}{2(m^2 - 2\,m + 4)^{\frac{1}{2}}}$$

$$= \frac{m}{4}\left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} - \frac{m}{4}\left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} + \left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}}$$

$$= \left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}}$$

From the polar equation of the circle, we have

$$r = r'\,(cos\ \theta - \theta_1) \pm \left[R^2 - r'^2\ sin^2\,(\theta - \theta_1)\right]^{\frac{1}{2}}$$

but $\theta_1 = o$, $r' = C\,O = \sqrt{\frac{3}{4}}$, $R = \frac{1}{2}$, and $\theta = D\,C\,O$.

therefore, $C\,F = r = r'\ cos\ \theta - (R^2 - r'^2\ sin^2\ \theta)^{\frac{1}{2}}$

$$= \sqrt{\frac{3}{4}} \cdot \frac{m}{2}\left(\frac{3}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} - \left[\frac{1}{4} - \frac{3}{4} \cdot \frac{(m-4)^2}{4(m^2 - 2\,m + 4)}\right]^{\frac{1}{2}}$$

$$= \frac{3}{4}m\left(\frac{1}{m^2 - 2\,m + 4}\right)^{\frac{1}{2}} - \left(\frac{4m^2 - 8m + 16 - 3m^2 + 24m - 48}{16\,(m^2 - 2\,m + 4)}\right)^{\frac{1}{2}}$$

$$= \frac{3}{4} \cdot \frac{m}{(m^2 - 2\,m + 4)^{\frac{1}{2}}} - \frac{1}{4}\left(\frac{m^2 + 16m - 32}{m^2 - 2m + 4}\right)^{\frac{1}{2}}$$

$$\overline{AF}^2 = \overline{AC}^2 + \overline{FC}^2 - 2\, AC \cdot FC \cos ACF,$$

$$= 1 + \left[\frac{1}{4} \cdot \frac{3m}{(m^2-2m+4)^{\frac{1}{2}}} - \frac{1}{4}\left(\frac{m^2+16m-32}{m^2-2m+4}\right)^{\frac{1}{2}}\right]^2 -$$

$$2\left[\frac{1}{4} \cdot \frac{3m}{(m^2-2m+4)^{\frac{1}{2}}} - \frac{1}{4}\left(\frac{m^2+16m-32}{m^2-2m+4}\right)^{\frac{1}{2}} \cdot \frac{m-1}{(m^2-2m+4)^{\frac{1}{2}}}\right]$$

which becomes, after some reduction,

$$AF = \left(\frac{m^2+4m+16-(m-4)(m^2+16m-32)^{\frac{1}{2}}}{8(m^2-2m+4)}\right)^{\frac{1}{2}}$$

But $AC : \sin AFC = AF : \sin ACF$,

$$\text{or } \sin AFC = \frac{AC \cdot \sin ACF}{AF}$$

$$\text{but } \sin ACF = \left(\frac{3}{m^2-2m+4}\right)^{\frac{1}{2}}$$

therefore as $AC = 1$,

$$\sin AFC = \frac{\left(\frac{3}{m^2-2m+4}\right)^{\frac{1}{2}}}{\left(\frac{m^2+4m+16-(m-4)(m^2+16m-32)^{\frac{1}{2}}}{8(m^2-2m+4)}\right)^{\frac{1}{2}}}$$

$$= \left(\frac{24}{m^2+4m+16-(m-4)(m^2+16m-32)^{\frac{1}{2}}}\right)^{\frac{1}{2}}$$

If this method be mathematically exact, the value for $\sin AFC$, being equal to the sine of its supplemental angle AFE, should be equal to $\sin\frac{\pi}{m}$, where m represents the number of sides of the polygon.

Making $m=3, \sin AFC = \left(\frac{24}{9+12+16-\sqrt{25}}\right)^{\frac{1}{2}} = \sqrt{\frac{24}{32}} = \sqrt{\frac{3}{4}}$

$$\text{which equals } \sin\frac{\pi}{3} = \sin 60^\circ = \frac{1}{2}\sqrt{3}.$$

For $m=4, \sin AFC = \sqrt{\frac{24}{48}} = \sqrt{\tfrac{1}{2}}$, which equals,

$$\sin\frac{\pi}{4} = \sin 45^\circ = \sqrt{\tfrac{1}{2}}$$

For $m=5$, $\sin AFC = \sqrt{\frac{24}{69.544}} = \sqrt{0.34501} = 0.5874$.

but the tables give $sin\frac{\pi}{5} = sin\ 36° = 0.5877$.

For $m=6, sin\ AFC = \sqrt{\frac{24}{96}} = \frac{1}{2}$ which equals $sin\frac{\pi}{6} = sin\ 30°$.

For $m = 8, sin\ AFC = 0.3841$, while the tables give

$$sin\frac{\pi}{8} = sin\ 22°\ 05' = 0.3826,$$

When m is greater than eight, the resulting differences between the value of $sin\ AFC$ and of $sin\frac{\pi}{m}$ continue to increase.

We see then that this method is only true for the special cases where m is equal to 3, 4, and 6, respectively.

F. A. WEIHE, '90.

INSPECTION OF HIGH-SPEED ENGINES BY THE SENIOR MECHANICAL ENGINEERS.

During the latter part of last term the Senior Mechanicals, accompanied by Mr. Breckenridge, visited New York and Newark to inspect the best types of steam engines which are in the market, and also electric light and boiler plants.

Several hours were spent at the Newark electric light plant, where several Ball engines are run at a very high speed. The works of Hewes & Phillips, who manufacture the Corliss engine, were also visited and the good points of the Corliss were investigated. The first place visited in New York was the New York Safety Steam Company, on Courtlandt street. The plant of this firm is extensive, and the arrangements to feed and manage their forty-eight large boilers, and the means for supplying draught, were looked into with interest. They use the Babcock & Wilcox water tube boiler, selecting this because it probably combines the advantages of economy of fuel, safety, good combustion, circulation of water and dryness of steam, better than any other type. The boilers are suspended from the floor beams of the building, and are supported independent of the brick work which surrounds them, thus enabling repairs to be made to one without disturbing others, and avoiding the strains which exist when the weight of a boiler is carried by its setting. This company use

over 400 tons of coal per day. The boilers are 250 horse-power; steam pressure between ninety and one hundred pounds.

The firm of E. P. Hampton & Co., 36 Courtlandt, were called upon, where some time was spent in comparing the relative merits of the Corliss and the Armington & Sims engines. The distinguishing feature of the former is its peculiar wrist-plate motion and valve gear, by means of which the steam valves are opened quickly, giving boiler pressure at closest cut-off, and kept in motion up to the point of extreme travel. The reversal of the valves is easy—without shock. A good deal is claimed for the disengaging valve gear. The advantages of the latter engine are: simplicity, regularity of speed, compact form, balanced valve always surrounded by live steam. By its unique construction, it permits the full boiler pressure to be maintained in the cylinder up to point of cut-off. The automatic cut-off regulator, which is on the wheel, is very neat and efficient. At the office of the Phœnix Iron Works, an opportunity was afforded to inspect the Dick & Church automatic cut-off engine and the Ball engines. The governors of both these engines are on the fly-wheel, and as they were not running, a good opportunity was afforded for investigation. A courteous reception was tendered at the headquarters for Westinghouse engines, and it was found that a good deal could be said about them. At the office of the Buckeye Company, two engines of this well-known type were examined. On Dey street, the firm of Fleming & Kimball and the Payne Engine Company were visited, who exhibited the Ide and the Payne engines respectively. The last call was on the Rider Hot Air Compression Company.

It was concluded that the Armington & Sims and the Ball high speed engines were the best for use in electric lighting where there is a severe test of the governing power.

PEARCE ATKINSON, '89.

ABSTRACT OF PROCEEDINGS.

Oct. 10, 1888.—President Villalon in the chair at 19:10 o'clock, with thirty-one members present. Professor Merriman delivered a very interesting address on "The Great Pyramid of Egypt," for which the thanks of the Society were tendered him.

Oct. 25.—The meeting was called to order by President Villa-

lon at 19:20 o'clock, with twenty-two members present. A paper on "The Catenary Curve" was read by Mr. J. R. Villalon, '89.

Nov. 15.—President Villalon called the meeting to order at 19:30 o'clock, with seventeen members present. Solutions of the problem "To Inscribe a Regular Polygon of any Number of Sides in a Circle," were presented by Messrs. E. A. Wright, '89, and F. A. Weihe, '90. This was followed by a debate on "Pin Connected *vs.* Rivetted Bridges." Messrs. Deans, '89, and Diebitsch, '89, championed the former and Messrs. Frescoln, '88, and E. A. Wright, '89, the latter.

Nov. 22.—A special meeting was held at 16:15 o'clock. Dr. Coppée delivered a very interesting address on "Impressions of a Trip to California," for which he received a vote of thanks from the Society. There were present thirty-one members and a large number of visitors.

Jan. 31, 1889.—President Villalon in the chair at 19:20 o'clock, with twenty-one members present. The following papers were read: "Backwater Caused by Bridge Piers and other Obstructions Placed in the Beds of Streams," by Mr. S. W. Frescoln, C. E., '88; "The Nicaragua Canal," by Mr. E. Diebitsch, '89.

A. W. Stockett, Sec'y.

EDITORIALS.

Mr. J. F. Merkle, C.E., '84, has been appointed an Instructor in the University to take the place of Mr. Spalding. Mr. Merkle had been for some time in the employ of the Fuel Gas and Electric Engineering Co., of Pittsburgh, Pa., as assistant engineer. He has in preparation for the Society a series of papers on the manufacture and use of coal gas, and the manipulation of natural gas as a heating agent.

We feel the need of aid from our alumni in the way of contributions to the Journal, and would especially ask those who have recently graduated to record some of the results of their experience for our benefit. They know something of the work which we attempt to do, and have some idea of the scope and character of the papers which should be presented to the Engineering Society. We respectfully ask for their coöperation, and shall be pleased to publish any articles with which they may choose to favor us.

A Treatise on Hydraulics, by Mansfield Merriman, Professor of Civil Engineering in Lehigh University.

It is with a feeling of satisfaction that we turn the leaves of this book. It

is a work of 381 pages (8vo.) divided into 13 chapters and 154 articles. Each chapter contains numerous examples, the solution of which involves the subject matter contained therein. There are 180 such examples in all, and they add much to its usefulness as a text book, for which it was mainly intended. The figures used to illustrate the principles are of the skeleton type and finely executed. Numerous tables of weights, pressures, velocities and coefficients for orifices, weirs, conduits, pipes and sewers run throughout the work. The theoretical deductions are made in a simple and concise manner, the calculus is seldom used, and there is an entire absence of the long and tedious formulas with which the student of Weisbach is familiar (?). Besides a complete discussion of the flow of water through orifices, tubes and pipes, over weirs, and in conduits, canals and rivers, the means of measuring water-power is presented. The conditions of high efficiency in the different kinds of water-wheels and turbines are pointed out. The last chapter is devoted to "Naval Hydromechanics," treating of the different methods of propulsion for boats.

The work shows much care and thought in its arrangement and in its methods of presenting the various subjects. Several new deductions have been brought out, and we feel assured that the work will be a success not only as a technical school text book but as a reliable source of information for engineers.

THERE has appeared to be a lack of interest in the Engineering Society this year, and the members do not seem to realize their responsibility in the matter. When the publication of the JOURNAL was first commenced, some four years ago, there was considerable enthusiasm among those connected with the enterprise, and we find that our earlier numbers contained a great many articles written by the students in the Engineering courses. While it is scarcely to be expected that the JOURNAL is to be entirely made up from articles contributed by undergraduates, there should be a much greater number of papers written by the members of the Society. We do not expect learned discussions of abstruse problems in celestial mechanics, nor do we ask for analyses of the stresses in a curved dam, but we do wish to have short practical articles upon every-day engineering. There are reasons of self-interest which should prompt us in this matter, in addition to our duty to the Society. The time will come when some of our members may find it necessary to prepare papers of a technical character which shall be subjected to literary as well as scientific criticism, and it is self-evident that in this matter as in many others, experience is one of the best instructors. There is not a member of the Society but that could find time for at least one paper a year during the last half of his college course. Professor Merriman is always glad to suggest subjects which are full of interest to all, and are accessible to the average student. There are many suggestive themes which may be found right here in our community, and they present a fruitful field for observation and investigation. Let the members of the Society become individually interested in this matter, and we will promise to have the JOURNAL out "on time" in the future.

ALUMNI NOTES.

1871.

—Jacob N. Barr, M.E., Superintendent of Motive Power of the Chicago, Milwaukee & St. Paul Ry., was elected a member of the American Society of Engineers, at the regular meeting in November. He read a paper on "The Contracting Chill in Wheel Making," before the New York Railroad Club, Dec. 20. This paper has received very favorable comments from the various railroad Journals, and several have particularly referred to its excellent arrangement. Mr. Barr's address is 3028 Wells Street, Milwaukee, Wis.

1872.

—R. F. Miranda, C.E., is a Division Engineer on the Rio de Janeiro & Northern R. R., his address being E. F. Principe da Grao Parà, Astaçao do Areal, Rio de Janeiro, Brazil.

1878.

—Milnor P. Paret, C E., has recently changed his position to that of U. S. Resident Engineer, stationed at Fernandina, Fla. His article on "The Construction of a Skew or Spiral Arch," appeared in the *Engineering News* for Oct. 20, 27, and Nov. 3. The only addition to the article as it originally appeared in the JOURNAL OF THE ENGINEERING SOCIETY for Feb. 1888, was an illustration from a photograph giving a general view of the arch.

1880.

—Fred. P. Spalding, C.E., is in charge of the surveys on the third district of the Mississippi River Improvement. His address is Wilson's Point, La.

1882.

—Eugene Ricksecker, C.E., the Engineer and Superintendent of the Puget Sound Creosote Co., at Seattle, Washington Ter., is coming East to purchase a lot of machinery for the works.

1884.

—Harry T. Harper, C.E., is at present on an engineer corps of the Northern Pacific Railroad, somewhere in Utah.

—Edwin F. Hofford, C.E., is the Secretary and Treasurer of the Birmingham & Bessemer Railroad Co., at Birmingham, Ala.

1885.

—Felix Freyhold, C.E., is an Assistant Engineer on the Duluth, Red Wing & Southern R. R. His address is St. James' Hotel, Red Wing, Minn.

—John R. Wagner, M.E., is the General Scientific Assistant to the Hon. Eckley B. Coxe, Drifton, Luzerne Co., Pa.

1886.

—Robert C. Gotwald, C.E., is an Assistant Engineer on the Missouri Pacific Ry., and may be addressed at Talmage, Neb.

1887.

—Robert W. Barrell, E.M., has gone to Cooney, Scott Co., N. M., where he has obtained the position of Assayer for the Mogollon Consolidated Mining Company.

—John W. La Doo, C.E., is at present stationed at Lycippus, Westmoreland Co., Pa., superintending some construction under the direction of C.W. Knight, Hydraulic Engineer.

—H. B. C. Nitze, B.S., E.M., is located at Anaconda, Montana Ter., being employed in the Assay Laboratory of the Anaconda New Smelting Works.

—George F. Pettinos, M.E., draughtsman for the Bethlehem Iron Co., has been assigned to the department of the new government plant.

—Charles P. Pollak, C.E., is employed as draughtsman in the office of the Mechanical Engineer of the Chicago, Milwaukee & St. Paul Ry., at Milwaukee, Wis.

1888.

—Chas. L. Addison, M.E., is with the Wharton Switch Co., at Jenkintown, Pa.

—Hubert A. Bonzano, C.E., is pursuing a post-graduate course of study at the University of Pennsylvania. Address: Phœnixville, Pa.

—Reuben Daniels, C.E., has recently been appointed Engineer for the Ford Plate-Glass Works, Pittsburgh, Pa.

—James B. Glover, Jr., M.E., is an Assistant to the Engineer of the Machinery Department of the Central Railroad and Banking Co. of Georgia, at Savannah, Ga.

—George A. Hart, M.E., is employed as draughtsman in the office of the Chief Engineer of the Georgia, Florida & Western R. R., at Savannah, Ga.

—Sterry H. Jencks, C.E., is employed as draughtsman with Henry Creswicke, C.E., Barrie, Ontario, Can.

—Chas. D. Marshall, C.E., is now engaged in the Shiffler Bridge Works, 47th Street, Pittsburgh, Pa.

—John H. Millholland, C.E., is employed in the office of the assistant engineer of the Schuylkill Division of the Pennsylvania R. R., at Reading, Pa.

—Chas. H. Miller, C.E., has accepted a position on the survey party of the third district of the Mississippi River Improvement. Address: Wilson's Point, La.

—Harry S. Morrow, M.E., is with W. Bakewell & Sons, Pittsburgh, Pa. His address remains unchanged: White Ash, Allegheny Co., Pa.

—Harry Palmer, C.E., is now on an Engineer Corps on the Pennsylvania Railroad.

—Chas. J. Parker, C.E., has accepted a position on the Engineer Corps of the Lehigh Valley R. R., his address being Mauch Chunk, Pa.

—William P. Richards, C.E., is engaged as an assistant to Mr. F. P. Spalding on the surveys of the third district of the Mississippi River. He may be addressed at Wilson's Point, La.

—William R. Sattler, M.E., is located at Bremen, Germany, being in the service of the North German Lloyd Steamship Co.

—Harvey M. Wetzel, C.E., has opened an office at 312 Fourth Street, Sioux City, Ia., as Civil Engineer and Surveyor.